# ADDITIONAL NOTES ON THE BEHAVIOR OF CERTAIN INSECTS TO DIFFERENT WAVE-LENGTHS OF LIGHT

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This paper covers the results obtained by testing the color responses of 22 species of insects, the notes thereon having accumulated since the first tests involving 18 species were made and reported upon in this JOURNAL for March 1941. The same apparatus was used and the same procedure was followed as were outlined in the March 1941 paper and there is no need to describe either again. Except where noted, adult stages were used and the physical intensities of the wave-lengths of the light were equalized by the methods previously described. In fact, this paper is, for the most part, an extension of the first one.

Twenty-two species, representing seven orders, were tested for 15 minutes for their color reactions and the results are outlined in Table 1. In addition, the behavior of these species is shown graphically on Plates 4 and 5 together with the behavior of those tested previously and reported in the first paper. These "behavior curves" should not be regarded as continuous records of the reactions of the insects to that portion of the electromagnetic spectrum from 3650 to 7400 ångstrom units. As a matter of fact, the insects were exposed to only eight bands, these having peaks of energy at .365, .436, .464, .492, .515, .606, .642, and .720 microns respectively.[1] In other words, each curve simply connects the points that represent the percentage distribution of the reacting numbers of each species, and gives one a rough idea of the relative responses of the species to certain wave-lengths in the spectrum, when light of equal energy or physical intensity was used. Conversely, the relative efficiency of wave-lengths of equal energy is demonstrated.

[1] These peaks occur in transmitted bands, extending as follows: 3650–3663; 4120–4760; 4420–5000; 4700–5280; 4940–5660; 5900–6420; 6120–6860; 6620–7400 ångstrom units. The order as given is identical with the order of the peaks. See JOUR. N. Y. ENT. SOC., Mar., 1941, p. 1–20.

TABLE 1

DISTRIBUTION IN PERCENTAGES OF NUMBER REACTING POSITIVELY TO DIFFERENT WAVE-LENGTHS

| Name | No. tests | Total No. insects involved | Per cent of total in centre | Per cent of total reacting | Wave-lengths of maximum transmission in microns | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | .365 | .436 | .464 | .492 | .515 | .606 | .642 | .720 |
| | | | | | *Per cent* | *Per cent* | *Per cent* | *Per cent* | *Per cent* | *Per cent* | *Per cent* | *Per cent* |
| Orthoptera | | | | | | | | | | | | |
| Gryllidæ | | | | | | | | | | | | |
| *Gryllus luctuosus* Serv. | 4 | 156 | 1 | 99 | 8.3 | 23.6 | 11.1 | 18.0 | 11.9 | 11.1 | 9.9 | 6.1 |
| Mantidæ | | | | | | | | | | | | |
| *Tenodera sinensis* Sauss. (1 day old) | 2 | 477 | 45 | 55 | 31.6 | 17.8 | 7.5 | 14.9 | 10.6 | 8.4 | 4.8 | 4.4 |
| Homoptera | | | | | | | | | | | | |
| Cicadellidæ | | | | | | | | | | | | |
| *Eutettix tenellus* Baker | 1 | 114 | 45 | 55 | 37.1 | 8.1 | 0.0 | 29.0 | 14.5 | 8.1 | 0.0 | 3.2 |
| *Agallia sanguinolenta* Prov. | 1 | 98 | 29 | 71 | 21.7 | 13.0 | 1.5 | 29.0 | 23.0 | 5.8 | 3.0 | 3.0 |
| *Macrosteles divisus* Uhl. | 1 | 96 | 18 | 82 | 30.0 | 2.5 | 0.0 | 37.1 | 25.4 | 0.0 | 2.5 | 2.5 |
| Hemiptera | | | | | | | | | | | | |
| Coreidæ | | | | | | | | | | | | |
| *Leptocoris trivittatus* Say | 3 | 209 | 4 | 96 | 25.5 | 10.5 | 7.0 | 21.5 | 19.0 | 6.0 | 6.0 | 4.5 |
| Coleoptera | | | | | | | | | | | | |
| Chrysomelidæ | | | | | | | | | | | | |
| *Diabrotica vittata* Fab. | 3 | 569 | 10 | 90 | 13.7 | 18.3 | 14.6 | 21.6 | 18.6 | 7.2 | 3.9 | 2.1 |
| Scarabæidæ | | | | | | | | | | | | |
| *Aphodius fimetarius* L. | 3 | 172 | 17 | 83 | 20.4 | 9.2 | 8.4 | 29.6 | 18.3 | 9.2 | 1.4 | 3.5 |
| Same insects 3 days later | 3 | 110 | 23 | 77 | 16.4 | 22.4 | 8.2 | 31.7 | 5.9 | 11.8 | 2.4 | 1.2 |
| *Aphodius distinctus* Muls. | 3 | 159 | 23 | 77 | 33.0 | 5.0 | 4.1 | 12.4 | 19.0 | 9.1 | 9.1 | 8.3 |
| Same insects 3 days later | 3 | 95 | 22 | 78 | 36.5 | 2.7 | 8.2 | 20.3 | 12.0 | 10.8 | 5.4 | 4.1 |
| *Popillia japonica* (Larvæ—3rd instar) | 4 | 299 | 62 | 38 | 10.4 | 14.9 | 11.3 | 2.6 | 9.5 | 14.9 | 20.8 | 15.6 |
| *Popillia japonica* 2nd lot (Larvæ—3rd instar) | 3 | 147 | 24 | 76 | 5.4 | 16.2 | 11.8 | 7.2 | 6.2 | 9.0 | 27.0 | 17.2 |
| Dermestidæ | | | | | | | | | | | | |
| *Dermestes vulpinus* Fab. (Full grown larvæ) | 1 | 106 | 21 | 79 | 18.6 | 9.2 | 4.6 | 10.4 | 14.0 | 4.6 | 28.2 | 10.4 |
| Tenebrionidæ | | | | | | | | | | | | |
| *Nyctobates pennsylvanica* DeG. | 12 | 93 | 25 | 75 | 15.1 | 9.0 | 6.0 | 10.7 | 9.1 | 17.8 | 15.6 | 16.7 |
| Bruchidæ | | | | | | | | | | | | |
| *Bruchus obtectus* Say | 3 | 1,117 | 20 | 80 | 19.0 | 9.0 | 6.0 | 26.0 | 16.0 | 12.0 | 5.0 | 7.0 |
| *Bruchus obtectus* Say (2nd lot) | 3 | 95 | 18 | 82 | 10.3 | 18.1 | 7.7 | 28.0 | 11.5 | 10.3 | 7.7 | 6.4 |

TABLE 1—(*Continued*)

| Name | No. tests | Total No. insects involved | Per cent of total in centre | Per cent of total reacting | Wave-lengths of maximum transmission in microns | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | .365 | .436 | .464 | .492 | .515 | .606 | .642 | .720 |
| | | | | | *Per cent* | *Per cent* | *Per cent* | *Per cent* | *Per cent* | *Per cent* | *Per cent* | *Per cent* |
| Diptera | | | | | | | | | | | | |
| Muscidæ | | | | | | | | | | | | |
| *Musca domestica* L. | 2 | 185 | 25 | 75 | 16.6 | 12.3 | 5.1 | 24.6 | 19.0 | 12.3 | 8.7 | 1.4 |
| Culicidæ | | | | | | | | | | | | |
| *Aedes ægypti* Linn. | 3 | 279 | 63 | 37 | 15.4 | 14.4 | 7.7 | 1.9 | 9.7 | 21.1 | 15.4 | 14.4 |
| Hymenoptera | | | | | | | | | | | | |
| Diprionidæ | | | | | | | | | | | | |
| *Neodiprion lecontei* Fitch (Full grown larvæ) | 1 | 60 | 100 | 0 | | | | | | | | |
| Braconidæ | | | | | | | | | | | | |
| *Triaspis thoracicus* (Males—European form) | 3 | 502 | 28 | 72 | 61.0 | 6.3 | 2.4 | 15.4 | 8.3 | 2.4 | 1.2 | 3.0 |
| Chalcididæ | | | | | | | | | | | | |
| *Microplectron fuscipennis* Zett. | 4 | 821 | 44 | 56 | 25.0 | 22.0 | 5.4 | 10.2 | 11.3 | 10.5 | 9.9 | 5.7 |
| Lepidoptera | | | | | | | | | | | | |
| Pyralidæ | | | | | | | | | | | | |
| *Galleria melonella* Linn. | 2 | 67 | 25 | 75 | 12.0 | 4.0 | 8.0 | 6.0 | 20.0 | 10.0 | 10.0 | 30.0 |
| *Achroia grisella* Fabr. (Larvæ) | 2 | 219 | 14 | 86 | 20.5 | 7.3 | 13.0 | 3.2 | 10.0 | 12.2 | 20.0 | 13.8 |
| Tineidæ | | | | | | | | | | | | |
| *Tineola biselliella* Hum. | 2 | 182 | 72 | 28 | 3.9 | 13.7 | 8.0 | 0.0 | 3.9 | 21.5 | 39.2 | 9.8 |
| Bombycidæ | | | | | | | | | | | | |
| *Bombyx mori* Linn. | 3 | 12 | 100 | 0 | | | | | | | | |
| *Bombyx mori* (Larvæ, 3rd instar) | 4 | 235 | 100 | 0 | | | | | | | | |

Some previous workers have concluded that photopositive insects appear to "see" ultra-violet better than the other parts of the spectrum, basing their conclusions on experiments in which light of unequal energy was used over different portions of the spectrum and then calculating the relative effects of equal energies.

Sanders[2] has questioned the validity of these methods, and in his work with the honey bee, he found that, when light of equal energy was used at all parts of the spectrum, there was no trace of a high maximum at 3650 ångstrom units.

An examination of the "behavior curves" from 1 to 28 inclusive, on Plates 4 and 5 indicates that Sanders' conclusion may be correct. The responses of the 29 species, which are all generally regarded as photopositive were, for the most part, remarkably constant with respect to certain characteristics. Of the 29 species, 18 showed a peak response at .492 microns (blue-blue-green), 7 at .365 microns (ultra-violet), 3 at .436 microns (violet-blue), and 1 at .515 microns (blue-green). In all cases the peaks took place between .365 and .566 microns, and the longer wave-lengths had comparatively little attractive value. The secondary peaks which occur in many of these curves appear quite significant, but at this time we are in no position to offer explanations for them. These "behavior curves," we believe, have value only in demonstrating the efficiency of certain wave-lengths as compared to others and in calling attention to the trend of behavior under the conditions of the experiments. The fact that small numbers of insects reacted positively to wave-lengths of apparently little stimulating value may be due to various factors such as certain physiological states, an unfavorable position when first placed in the testing box which resulted in the insects not being truly oriented to the most stimulating wave-lengths, or to other factors which reduced their receptivity.

The "behavior curves" of *Gryllus luctuosus* (7), *Diabrotica vittata* (13A), *Anasa tristis* (18), *Musca domestica* (20) and *Bruchus obtectus* (21, 25) do not exhibit pronounced peaks as do many of the other photopositive species. Without attempting

[2] Sanders, W., Z. vergl. Physiol., 20 (1933), 267–86 (response to light of different wave-length in honey bee).

TABLE 2

| Name | Date tested | Relative humidity during test | Temperature °C. | |
|---|---|---|---|---|
| | | | At start of test | At end of test |
| | | *Per cent* | | |
| *Gryllus luctuosus* Serv. | Sept. 27, 1940 | 50 | 24.0 | 25.0 |
| *Tenodera sinensis* Sauss. (1 day old nymphs) | Dec. 31, 1940 | 36 | 24.0 | 26.0 |
| *Eutettix tenellus* Baker | Nov. 8, 1940 | 36 | 25.0 | 26.0 |
| *Agallia sanguinolenta* Prov. | Nov. 8, 1940 | 36 | 25.0 | 26.0 |
| *Macrosteles divisus* Uhl. | Nov. 8, 1940 | 36 | 25.0 | 26.0 |
| *Leptocoris trivittatus* Say | Oct. 14, 1940 | 50 | 23.0 | 24.5 |
| *Diabrotica vittata* Fab. | Nov. 7, 1940 | 40 | 22.7 | 24.0 |
| *Aphodius fimetarius* L. | Oct. 29, 1940 | 38 | 25.5 | 26.0 |
| *Aphodius fimetarius*, same lot | Nov. 1, 1940 | 44 | 25.0 | 27.0 |
| *Aphodius distinctus* Muls. | Oct. 29, 1940 | 38 | 25.0 | 26.5 |
| *Aphodius distinctus*, same lot | Nov. 1, 1940 | 50 | 24.0 | 25.0 |
| *Popillia japonica*, larvæ | Oct. 1, 1940 | 48 | 24.0 | 25.0 |
| *Popillia japonica*, larvæ, 2nd lot | Oct. 29, 1940 | 38 | 26.0 | 26.5 |
| *Dermestes vulpinis* Fab., larvæ | Oct. 25, 1940 | 46 | 23.0 | 24.0 |
| *Nyctobates pennsylvanica* DeG. | Nov. 9, 1940 | 38 | 23.0 | 25.0 |
| *Bruchus obtectus* Say | Nov. 26, 1940 | 40 | 21.0 | 24.0 |
| *Bruchus obtectus*, 2nd lot | Jan. 14, 1941 | 30 | 23.0 | 24.0 |
| *Musca domestica* L. | Dec. 9, 1940 | 36 | 23.5 | 24.5 |
| *Aedes ægypti* L. | Dec. 23, 1940 | 34 | 23.0 | 25.0 |
| *Neodiprion lecontei* Fitch | Oct. 25, 1940 | 42 | 26.0 | 27.0 |
| *Triaspis thoracicus* | Dec. 4, 1940 | 28 | 23.0 | 25.0 |
| *Microplectron fuscipennis* Zett. | Dec. 14, 1940 | 40 | 21.5 | 23.5 |
| *Galleria melonella* Linn. | Dec. 16, 1940 | 40 | 21.5 | 22.5 |
| *Achroia grisella* Fab., larvæ | Jan. 6, 1941 | 38 | 22.0 | 23.0 |
| *Tineola biselliella* Hum. | Jan. 10, 1941 | 36 | 24.0 | 26.0 |
| *Bombyx mori* Linn. | Nov. 6, 1940 | 40 | 24.0 | 25.0 |
| *Bombyx mori*, larvæ | Oct. 8, 1940 | 60 | 24.0 | 25.0 |

to explain the reasons for this, it should be mentioned that *Gryllus luctuosus, Diabrotica vittata,* and *Anasa tristis* were about ready for hibernation when they were tested. One does not expect pronounced responses to light from insects that are about to hibernate or from the housefly, which is seemingly indifferent to light except when disturbed. Dates tested, relative humidity and temperatures are found in Table 2. The fact that all species do not behave similarly under similar conditions is shown by the behavior of the 7 species that peaked at .365 microns (ultraviolet).

The similarity of the behavior of different lots of the same species or of successive tests of the same lot of specimens is shown by "behavior curves" 21 and 25, and 23 and 24. The first lot of *Bruchus obtectus,* in which 1117 insects were involved, reacted as shown by curve 21. The second lot, in which 95 insects were tested about 50 days later, reacted as shown by curve 25. For the most part the curves are similar. The two curves in each of the figures 23 and 24 represent the behavior of the same individuals three days apart. They follow the same trend.

For the photopositive species that were tested under the conditions described, it may be stated that, with lights of equal energy, wave-lengths from 3650 to 5660 ångstrom units had a decided stimulating value, and that within this portion of the spectrum, a band of from 4700 to 5280 ångstrom units had the greatest stimulating value for most of the species. With the equalization of the physical intensities of our lights, the responses obtained from the photopositive species should be due to wave-length alone.

Although the apparatus in use was not designed for testing the behavior of photonegative insects, the reactions of eight photonegative species are reported as a matter of interest. As it was impossible, on account of the circular arrangement of the chambers, to have one that was completely dark, the same filters and the same arrangements were used for both photopositive and photonegative insects, and all lights were of equal energy. A description of the equipment and methods will be found in our first paper published in this JOURNAL for March 1941.

The results of the tests of the photonegative species are found both in Table 1 and on Plate 2, numbers 29 to 38. It will not do to draw many conclusions from the "behavior curves" 29 to 38. They have certain characteristics in common. For the most part the peaks occur in that portion of the spectrum with wave-lengths from 5900 to 7400, and the band 4700–5280, that was the most attractive to the photopositive species, was the least attractive one for the photonegative species. Aside from the decided negative reaction to 4700–5280 ångstrom units, the balance of the behavior as recorded may not be a positive movement to certain wave-lengths, so much as a dispersal in search of darkness which could not be found, and the wave-lengths in which the peaks occur may represent those that were least objectionable rather than attractive. The two tests of Japanese beetle larvæ (34) represent two different lots with a month between the tests. Their behavior in both cases was almost identical.

Species which failed to react either photopositively or photonegatively were silk-worm adults and larvæ, *Bombyx mori* L., and the larvæ of *Neodiprion lecontei* Fitch. The latter saw-fly larvæ were full grown and about to pupate. In the case of the silk-worm adults and larvæ, this species has been under domestication for so many years that it appears to have lost its capacity for responses to some stimuli that activate other species.

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PLATE IV

Figure 1. *Leptinotarsa decemlineata.*
Figure 2. *Epicauta pennsylvanica.*
Figure 3. *Epilachna corrupta.*
Figure 3A. *Chrysochus auratus.*
Figure 4. *Chauliognathus pennsylvanicus.*
Figure 5. *Galerucella notata.*
Figure 6. *Chalepus dorsalis.*
Figure 7. *Gryllus luctuosus.*
Figure 8. *Scolytus multistriatus.*
Figure 9. *Hylurgopinus rufipes.*
Figure 10. *Rhyssematus lineaticollis.*
Figure 11. *Cyllene robiniæ.*
Figure 12. *Popillia japonica.*
Figure 13. *Tetraopes* spp.
Figure 13A. *Diabrotica vittata.*
Figure 14. *Macrosteles divisus.*
Figure 15. *Agallia sanguinolenta.*
Figure 16. *Eutettix tenellus.*
Figure 17. *Leptocoris trivittatus.*
Figure 18. *Anasa tristis.*
Figure 19. *Corythucha ciliata.*
Figure 20. *Musca domestica.*
Figure 21. *Bruchus obtectus.*
Figure 22. *Triaspis thoracicus* (males).
Figure 23. *Aphodius fimetarius* (dotted line, same insects tested 3 days later).
Figure 24. *Aphodius distinctus* (dotted line, same insects, 3 days later).

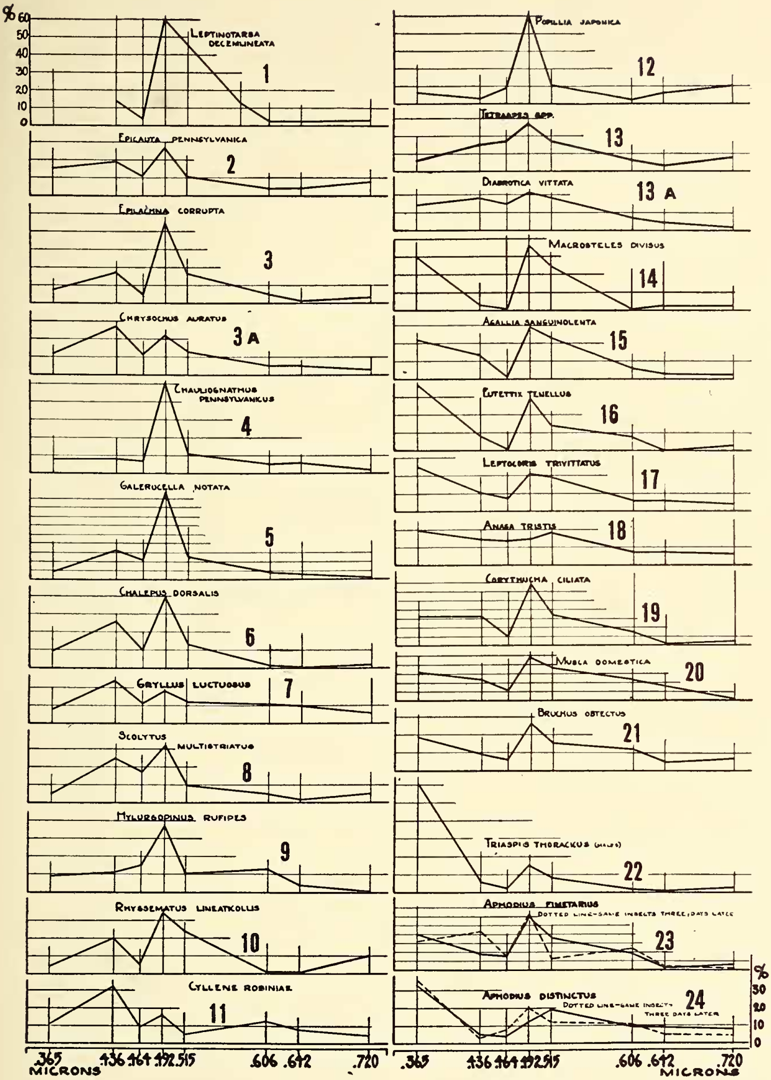
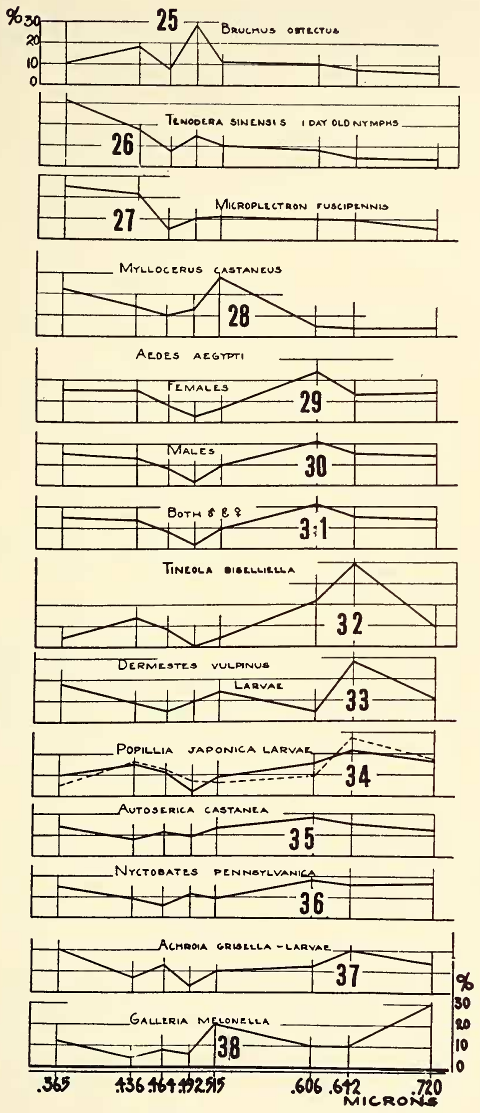

%
60
50
40
30
20
10
0
Leptinotarsa decemlineata
1
Epicauta pennsylvanica
2
Epilachna corrupta
3
Chrysochus auratus
3 A
Chauliognathus pennsylvanicus
4
Galerucella notata
5
Chalepus dorsalis
6
Gryllus luctuosus
7
Scolytus multistriatus
8
Hylurgopinus rufipes
9
Rhyssematus lineaticollis
10
Cyllene robiniae
11
Popillia japonica
12
Tetraopes spp.
13
Diabrotica vittata
13 A
Macrosteles divisus
14
Agallia sanguinolenta
15
Eutettix tenellus
16
Leptocoris trivittatus
17
Anasa tristis
18
Corythucha ciliata
19
Musca domestica
20
Bruchus obtectus
21
Triaspis thoracicus
22
Aphodius fimetarius
Dotted line—same insects three days later
23
Aphodius distinctus
Dotted line—same insects three days later
24
%
30
20
10
0
.365 .436 .464 .492 .515 .606 .642 .720
Microns

PLATE V

Figure 25. *Bruchus obtectus.*
Figure 26. *Tenodera sinensis* (1-day-old nymphs).
Figure 27. *Microplectron fuscipennis.*
Figure 28. *Myllocerus castaneus.*
Figure 29. *Aedes ægypti* (females).
Figure 30. *Aedes ægypti* (males).
Figure 31. *Aedes ægypti* (males and females).
Figure 32. *Tineola bisselliella.*
Figure 33. *Dermestes vulpinus* (larvæ).
Figure 34. *Popillia japonica* (larvæ) (dotted line represents testing of a second lot).
Figure 35. *Autoserica castanea.*
Figure 36. *Nyctobates pennsylvanica.*
Figure 37. *Achroia grisella* (larvæ).
Figure 38. *Galleria melonella.*


%
30
20
10
0
25
BRUCHUS OBTECTUS
TENODERA SINENSIS 1 DAY OLD NYMPHS
26
MICROPLECTRON FUSCIPENNIS
27
MYLLOCERUS CASTANEUS
28
AEDES AEGYPTI
FEMALES
29
MALES
30
BOTH ♂ & ♀
31
TINEOLA BISELLIELLA
32
DERMESTES VULPINUS
LARVAE
33
POPILLIA JAPONICA LARVAE
34
AUTOSERICA CASTANEA
35
NYCTOBATES PENNSYLVANICA
36
ACHROIA GRISELLA - LARVAE
37
GALLERIA MELONELLA
38
.365
.436
.464
.492
.515
.606
.642
.720
MICRONS